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Influence of edge rolling reduction on plate-edge stress distribution during finish rolling

Abstract

Dimensions of one kind of stainless steel plate before finish rolling were obtained through analysis of the rough rolling processes by finite element method and updated geometrical method. The FE models of finish rolling process with a front edge roll were built, and influences of the edge rolling reduction on the stress change in the plate edge during finish rolling were analyzed. The results show that when the edge rolling reduction is increased from 0 mm to 2 mm, the compressive stress in plate corner clearly increases in edge rolling process, and the zone of tensile stress during whole rolling decreases; when the edge rolling reduction is increased from 2 mm to 5 mm, the compressive stress in the plate corner seldom changes, and the compressive stress decreases after the horizontal rolling.

Keywords

during, distribution, stress, plate, reduction, finish, rolling, influence, edge

Disciplines

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Influence of Edge Rolling Reduction on Plate-Edge Stress Distribution During Finish Rolling

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Abstract: Dimensions of one kind of stainless steel plate before finish rolling were obtained through analysis of the rough rolling processes by finite element method and updated geometrical method. The FE models of finish rolling process with a front edge roll were built, and influences of the edge rolling reduction on the stress change in the plate edge during finish rolling were analyzed. The results show that when the edge rolling reduction is increased from 0 mm to 2 mm, the compressive stress in plate corner clearly increases in edge rolling process, and the zone of tensile stress during whole rolling decreases; when the edge rolling reduction is increased from 2 mm to 5 mm, the compressive stress in the plate corner seldom changes, and the compressive stress decreases after the horizontal rolling.

Key words: edge rolling reduction; stress; FEM; finish rolling

In stainless steel rolling process, the plate edge cracks might appear because of inclusions and uneven deformation in plate edge, etc^[1]. It is significant for reduction of the plate edge cracks through improvement of the rolling technology without change of the existing rolling equipments. Vertical-horizontal (V-H) rolling process is a kind of important rolling technology, which is widely used for the plate width reduction and the plane view pattern. Some of the researchers used the finite element method (FEM) to analyze the plate deformation behavior in V-H rolling process. For example, LIU Hui et al^[2] analyzed the effect of edger shape on the plate profile by explicit dynamic FEM; XIONG Shang-wu et al^[3,4] analyzed the slab spread and the unstable problems during V-H rolling with a rigid FE code, which was developed by themselves; Authors simulated the slab deformation behavior in multipass V-H rolling process by FEM and updating geometric method (UGM)^[5] and analyzed the influences of the fillet radii of grooved edge roll on the deformation of slab head and tail^[6]. Meanwhile, the closure and growth of the surface transversal cracks on slab cor-

ner during V-H rolling process were also analyzed by authors^[7]. However, compared with the large deformation of plate during V-H rolling, the plate deformation in edge rolling before finish rolling is very small, and there are no available reports on the influence of the edge rolling reduction on the plate edge cracks by FEM so far.

In this article, the deformation behaviors of one kind of stainless steel plate during the rough rolling process and the finish rolling process (the edge rolling and the first stand of horizontal rolling) were simulated by FEM and UGM. The influences of the edge rolling reduction on the plate-edge stress distribution and change were analyzed, and its effects on plate edge cracks were also discussed.

1 FE Analysis

1.1 Rolling conditions and parameters

The plate deformation during the rough rolling process and the finish rolling process was simulated. In this study, the influence of the edge rolling reduction before finish rolling on the plate edge stress during finish rolling was analyzed, and the parame-

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ters about the rough rolling process were not included. The diameter of edge roll is 630 mm, and the diameter of work roll of the first stand of finish mills is 825 mm. The plate dimensions before finish rolling were obtained through the analysis of the slab deformation in the rough rolling processes by FEM and UGM. The dimensions of plate profile before the rough rolling are 1 250 mm × 200 mm, and the plate thickness after the rough rolling process is 40 mm. The rigid model was used for rolls and the bilinear isotropic material model was used for plates. The edge rolling reductions are 0 mm, 1 mm, 2 mm, 3 mm, 4 mm, and 5 mm, respectively, and the draught of the horizontal rolling is 21 mm. During the simulation, other rolling conditions and parameters are shown in Table 1, and the simulation flow chart is shown in Fig. 1.

1.2 FE models

Owing to the phenomenon of surface interlayer in the slab head and tail during the rough rolling process [as shown in Fig. 2 (a)] and the symmetry of the rolls and the plate, a half of rolling model is used in FE models. After rough rolling process, the plate head and tail are cropped, so the plate geomet-

rical models in finish rolling are obtained through extruding the area of plate section obtained by the results of the slab deformation in the rough rolling processes. The models are meshed by the 8-node and hexahedron elements. Owing to the deformation in plate edge, the elements in plate edge are refined. The geometrical model and meshing of the finish rolling process with the edge roll is shown in Fig. 2 (b). The nodes at the middle cross section of plate are constrained along strip thickness direction. In rolling process, the rolls rotate with a uniform speed, and the plate enters the rolls with an initial velocity.

Table 1 Main parameters and rolling conditions

Parameter	Value
Friction coefficient	0.35
Rolling velocity/(m · s ⁻¹)	0.8
Roll	
Young's modulus/GPa	210
Poisson's ratio	0.3
Density/(kg · m ⁻³)	7 850
Plate	
Young's modulus/GPa	117
Poisson's ratio	0.36
Density/(kg · m ⁻³)	7 850
Deformation resistance/MPa	120

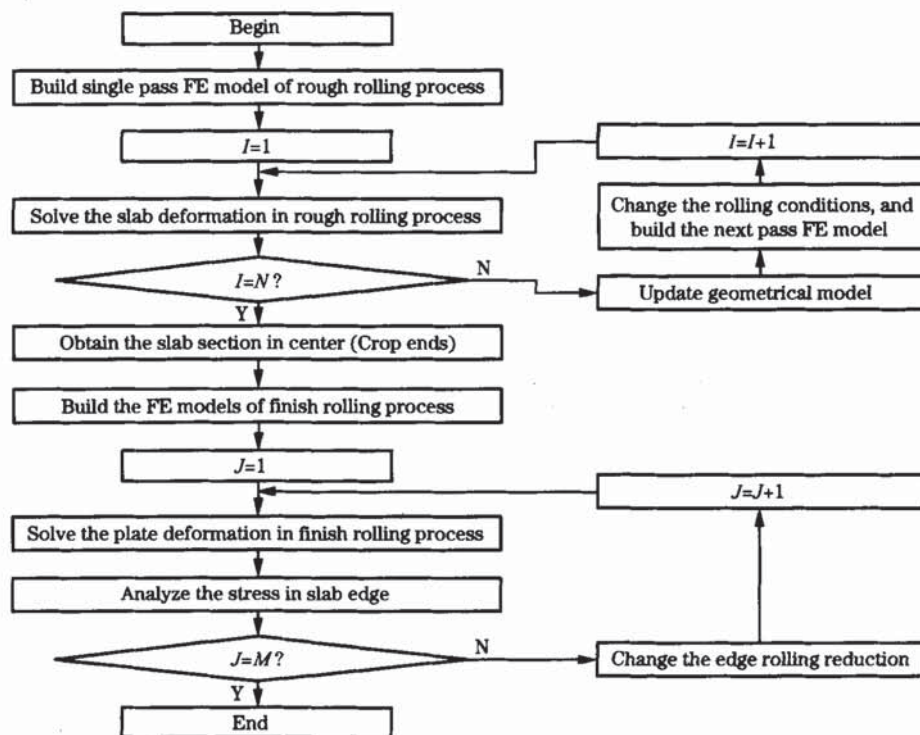


Fig. 1 Simulation flow chart

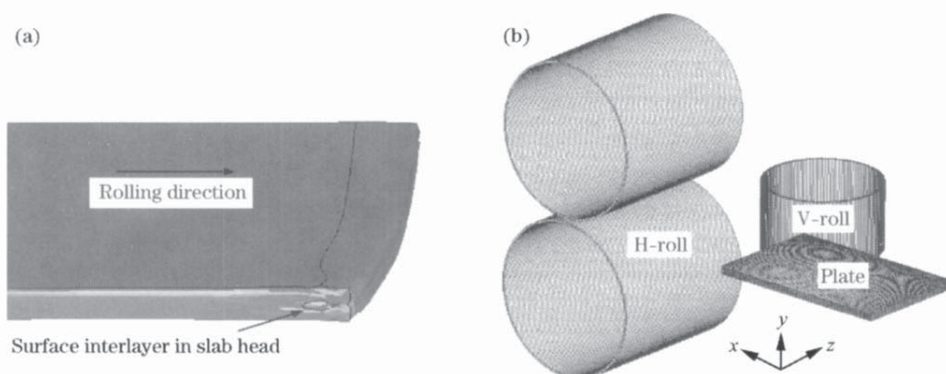


Fig. 2 Meshing and rolling models of rough rolling (a) and finish rolling (b)

2 Results and Analysis

Fig. 3 shows the stress distribution (σ_x) in rolling process with the reduction of 5 mm in edge rolling. It can be seen from the figure that the plate deformation in edge rolling mainly assembles in plate edge, and the stress is mainly compressive stress. However, in horizontal rolling process, there exists the tensile stress in plate edge, which is much less than the deformation resistance of plate.

The cracks might appear at the plate corner for the discontinuous plane and the uneven cooling velocity, etc. To discover the influence of the edge rolling reduction on the closure and growth of the

plate edge cracks, two points are marked in plate edge as shown in Fig. 4. The relationship between the σ_x in these points and the rolling time is built, and the influence of the edge rolling reduction on the change of stress in plate corner is analyzed.

Fig. 5 shows the relationship between the stress σ_x in Points 1 and 2 and the rolling time during rolling, where (a) is for Point 1 and (b) for Point 2. During edge rolling, when the edge-rolling reduction increases from 0 mm to 2 mm, the compressive stress increases, and when the edge-rolling reduction increases from 3 mm to 5 mm, the compressive stress seldom changes. During horizontal rolling, the tensile stress appears wherein the maximum value

$$\begin{aligned} A &= -0.136 \times 10^9 & D &= -0.526 \times 10^8 & G &= 0.306 \times 10^8 \\ B &= -0.108 \times 10^9 & E &= -0.249 \times 10^8 & H &= 0.583 \times 10^8 \\ C &= -0.804 \times 10^8 & F &= 0.282 \times 10^7 & I &= 0.860 \times 10^8 \end{aligned}$$

$$\begin{aligned} A &= -0.248 \times 10^9 & D &= -0.124 \times 10^9 & G &= 28\,996 \\ B &= -0.206 \times 10^9 & E &= -0.826 \times 10^8 & H &= 0.413 \times 10^8 \\ C &= -0.165 \times 10^9 & F &= -0.413 \times 10^8 & I &= 0.825 \times 10^8 \end{aligned}$$

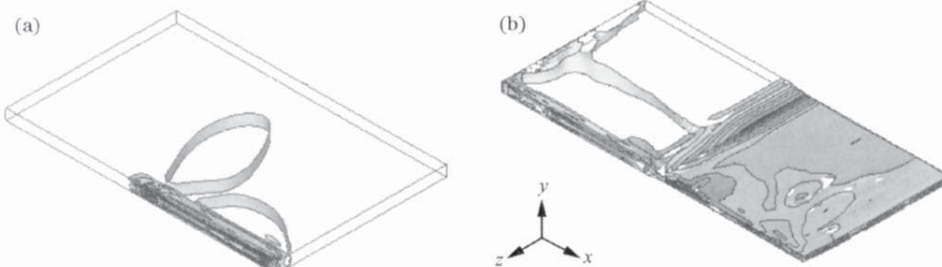


Fig. 3 σ_x (Pa) distribution on plate during edge rolling (a) and horizontal rolling (b)

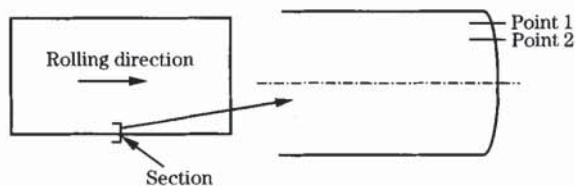


Fig. 4 Points in plate

does not change with the change of the edge-rolling reduction, and the tensile stress zone decreases with the increase in the edge-rolling reduction. After horizontal rolling, the tensile stress decreases and the compressive stress appears again.

With the increase in the edge-rolling reduction during rolling, the plate edge gradually deforms and forms a dog-bone shape, as shown in Fig. 6. Because

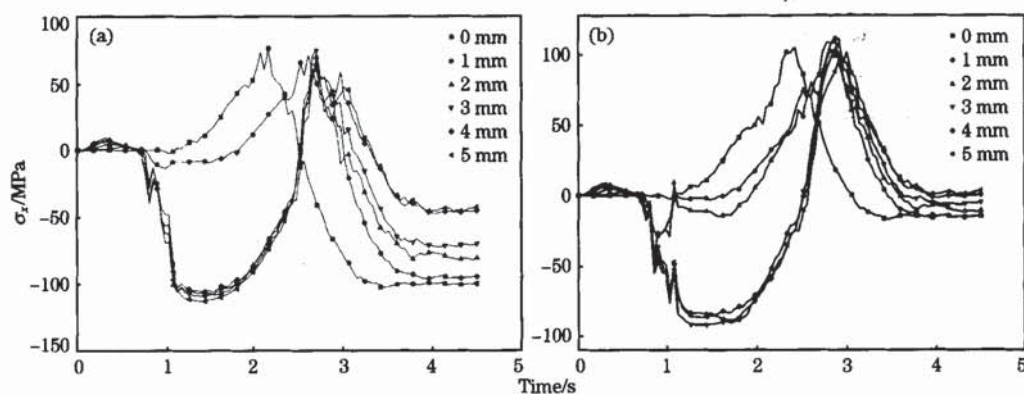


Fig. 5 Plate edge metal stress change regularity during rolling process at Point 1 (a) and Point 2 (b)

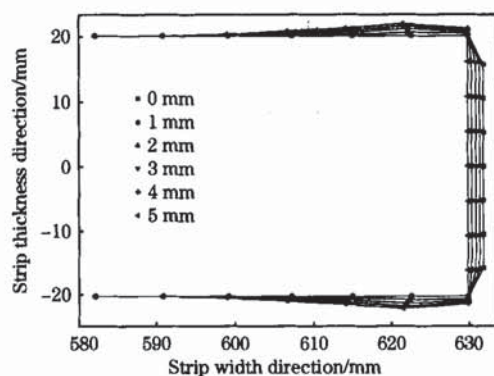


Fig. 6 Dog-bone in plate edge

the edge-rolling reduction is very small (no more than 5 mm), the dog-bone shape is very small. When the edge-rolling reduction is between 0 mm and 2 mm, the deformation of plate mainly assembled in the plate edge drop zone and just the edge drop zone gradually decreases, and there is no deformation of the dog-bone shape. When the edge-rolling reduction increases from 3 mm to 5 mm, the edge drop zone of plate disappears and a small dog-bone shape deforms; meanwhile, the influence zone of dog-bone seldom changes and just the maximum height of dog-bone shape increases. In Ref. [8], the influence of dog-bone shape on the change of stress in plate corner was discussed, and it was found that the effect of the maximum height of dog-bone shape on the change of stress in plate corner was very small. According to this result, when the edge drop zone in plate disappears in edge rolling process, the stress changes little when still increasing the edge rolling reduction. Hence, there is no benefit for improving the quality of plate edge to overfull increase the edge rolling reduction. In contrast, as shown in Fig. 7, the

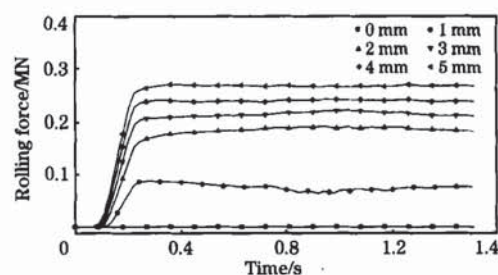


Fig. 7 Rolling force in edge rolling

rolling force in edge rolling remarkably increases with the increase in reduction of edge roll. Because the ratio of the plate width to the plate height is very large, according to the single-beam theory, as the rolling force increases, the possibility of destabilization of plate increases, which makes the rolling process unstable. Meanwhile, as shown in Table 2, the values of rolling forces calculated by FEM are in good agreement with those calculated by the Stone formula except the edge rolling reduction equals 1 mm, which is mainly affected by the plate edge drop.

Owing to the inclusion and the micro-cracks existing in the edge of stainless steel plate, the defects might grow into macroscopic edge cracks or transversal cracks^[1] in hot rolling process. The plate edge stress distribution is shown in Fig. 3 (a) when the edge roll is used before finish rolling, where the stress is mainly compressive stress, which makes the cracks and other defects close or welded in a certain degree, and then decreases the edge cracks in the subsequent rolling process. The relationship between the edge rolling reductions and the closure of crack in plate edge needs further researches and discussion.

Table 2 Rolling forces between FEM and analysis method

Reduction of edge rolling/mm		0	1	2	3	4	5
Rolling force/kN	FEM	0	85	183	212	238	269
	Stone formula	0	120	171	209	242	271

3 Conclusions

(1) The deformation behaviors of one kind of stainless steel plate in the rough rolling processes and the finish rolling processes are simulated by finite element method and updating geometrical method, and the influence of the edge-rolling reduction in finish rolling process on the stress in plate edge is analyzed.

(2) When the edge-rolling reduction increases from 0 mm to 2 mm, the compressive stress increases in edge rolling process and the tensile stress zone decreases in horizontal rolling process. When the edge-rolling reduction increases from 3 mm to 5 mm, the compressive stress seldom changes during edge rolling. The compressive stress decreases after the horizontal rolling process.

(3) With the increase in the edge-rolling reduction from 0 mm to 5 mm, the edge drop zone in plate disappears and the dog-bone shape deforms gradually; in the meanwhile, the influence zone of dog-bone changes little, and the maximum height of dog-bone shape increases.

References

- [1] JI Zhi-lei, SHI Rong-hua. Study on Formation Cause of Severe Cracked Edge of Stainless Steel Plate During Hot Continuous Rolling [J]. *BaoSteel Technology*, 2000, 18(1): 20 (in Chinese).
- [2] LIU Hui, GAO Cai-ru, WANG Guo-dong, et al. Affection of Edger Shape on the Plate Profile [J]. *Journal of Plasticity Engineering*, 2003, 10(5): 86 (in Chinese).
- [3] XIONG Shang-wu, LIU Xiang-hua, WANG Guo-dong, et al. A Three-Dimensional Finite Element Simulation of the Vertical-Horizontal Rolling Process in the Width Reduction of Plate [J]. *J Mater Process Technol*, 2000, 101(1): 146.
- [4] XIONG Shang-wu, ZHENG Gui-fang, LIU Xiang-hua, et al. Analysis of the Non-Steady State Vertical-Horizontal Rolling Process in Roughing Trains by the Three-Dimensional Finite Element Method [J]. *J Mater Process Technol*, 2002, 120(1-3): 53.
- [5] YU Hai-liang, LIU Xiang-hua, ZHAO Xian-ming, et al. FEM Analysis for V-H Rolling Process by Updating Geometric Method [J]. *J Mater Process Technol*, 2006, 180(1-3): 323.
- [6] YU Hai-liang, LIU Xiang-hua, LI Chang-sheng. Influence of Groove Fillet Radii of Edge Roll on Plate Deformation [J]. *Iron and Steel*, 2006, 41(6): 47 (in Chinese).
- [7] YU Hai-liang, LIU Xiang-hua, LI Chang-sheng, et al. Behavior of Transversal Crack on Plate Corner During V-H Rolling Processes [J]. *J Iron Steel Res Int*, 2006, 13(6): 31.
- [8] YU Hai-liang, LIU Xiang-hua, LI Chang-sheng, et al. Research on the Corner Stress of Dog-Bone Shaped Workpiece During Flat Spread Rolling [J]. *Journal of Northeastern University (Natural Science)*, 2006, 27(11): 1228 (in Chinese).